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ABSTRACT

A study investigated the combinatorial semantics of nouns and verbs in sentences: specifically, the phenomenon of meaning adjustment under semantic strain, in an effort to discover whether there are orderly processes of adjustment, and if so, to describe them. The study comprised three experiments. Experiments 1 and 2, tested the hypothesis that the semantic structures conveyed by verbs and other predicate terms are more likely to be altered to fit the context than are the semantic structures conveyed by object-reference terms. In these experiments, subjects (137 university students) paraphrased simple sentences in which verbs and nouns were combined with varying degrees of semantic strain. Results confirmed that verbs alter meaning more than nouns do. The second question, investigated in experiments 3a and 3b, involving 64 university students, was how this meaning adjustment takes place. Results indicated that although meaning adjustment is initiated in response to a mismatch with context, it is nevertheless characterized by orderly semantic processes. (Two tables of data and 9 figures are included, and 55 references are attached.) (Author/MG)

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CENTER FOR THE STUDY OF READING

Technical Report No. 503

THE VERB MUTABILITY EFFECT: STUDIES OF THE COMBINATORIAL SEMANTICS OF NOUNS AND VERBS

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Abstract

This report investigates the combinatorial semantics of nouns and verbs in sentences: specifically, the phenomenon of meaning adjustment under semantic strain. We wished to discover whether there are orderly processes of adjustment, and if so, to describe them. The first issue in semantic adjustment is the locus of change. Gentner (1981b) proposed the verb mutability hypothesis: that the semantic structures conveyed by verbs and other predicate terms are more likely to be altered to fit the context than are the semantic structures conveyed by object-reference terms. To test this claim, in Experiments 1 and 2 subjects paraphrased simple sentences in which verbs and nouns were combined with varying degrees of semantic strain: for example, "The daughters weakened," or "The lizard worshipped." The resulting paraphrases were analyzed for change of meaning in three different ways. The results confirmed that verbs alter meaning more than nouns do. The second question is how this meaning adjustment takes place. In particular, is meaning adjustment governed by orderly semantic processes, or is it primarily pragmatic and context-driven? This question was investigated in Experiments 3a and 3b. The results indicate that although meaning adjustment is initiated in response to a mismatch with context, it is nevertheless characterized by orderly semantic processes.

THE VERB MUTABILITY EFFECT: STUDIES OF THE COMBINATORIAL SEMANTICS OF NOUNS AND VERBS

This report investigates the combinatorial semantics of nouns and verbs in sentences: specifically, the phenomenon of meaning adjustment under semantic strain. The first issue in semantic adjustment is the locus of change. Gentner (1981b) proposed the verb mutability hypothesis: that the semantic structures conveyed by verbs and other predicate terms are more likely to be altered to fit the context than are the semantic structures conveyed by object-reference terms. To test this claim, in Experiments 1 and 2 subjects paraphrased simple sentences in which verbs and nouns were combined with varying degrees of semantic strain: for example, "The daughters weakened," or "The lizard worshipped." The resulting paraphrases were analyzed for change of meaning in three different ways. The results confirmed that verbs alter meaning more than nouns do.

The second question is how this meaning adjustment takes place. In particular, is meaning adjustment governed by orderly semantic processes, or is it primarily pragmatic and context-driven? This question was investigated in Experiments 3a and 3b. The results indicate that, although meaning adjustment is initiated in response to a mismatch with context, it is nevertheless characterized by orderly semantic processes. This report concerns combination of meaning: specifically, how the meanings of nouns and verbs combine to make new sentence meanings. We focus on cases where the noun and verb are semantically ill-matched. Understanding such cases is useful not only in explaining metaphorical extension but also in constraining the set of explanations that can apply in normal sentence processing. When simple straightforward combinations such as

The professor pondered.

are considered, it is difficult to know how much of the processing is new and how much is invoking of prestored structures. But now consider a semantically strained combination, such as "The butterfly pondered." For sentences like this, in which the noun and verb are semantically ill-matched, we can be fairly sure that the meaning is not prestored: some kind of active combinatorial processing must take place during interpretation.

How are such sentences interpreted? It could be that such sentences are simply uninterpretable anomalies, as some construals of Chomsky's (1965) selectional restriction would suggest. Assuming that interpretation is possible, this presumably requires some kind of meaning adjustment. Therefore the first question is where this adjustment typically takes place. One linguistically attractive view is that the verb will dominate the sentence meaning, and the noun will be reinterpreted to fit the semantic restrictions imposed by the verb. For example, given "The butterfly pondered," a hearer would resolve the conflict between noun and verb by altering the noun: for example, by deciding that "butterfly" referred to a person wearing bright-colored clothes, or perhaps to a particularly insouciant person. This view was put forth by Chafe (1970) and other linguists as part of a general verb-centered model of sentence meaning. It arose from the intuitively plausible view that the verb provides the organizing framework for the representation of a sentence. The conception of verb centrality has been an important part of theories of sentence meaning since the advent of case grammar (Fillmore, 1966; 1968). The psychological interpretation of case grammar was that the verb is the central relational element in a sentence, around which the nouns cluster, each related to the central event by its own thematic relation--who did it, with what, to whom, and so on (Fillmore, 1966; 1968). Verb-centered sentence representations have been used in all areas of cognitive science: psychology (Kintsch, 1974; Norman & Rumelhart, 1975), computer science (Schank, 1973; 1974), and linguistics (Chafe, 1970; Fillmore, 1966; 1968). In addition to being an important theoretical notion, verb centrality has received empirical support in tasks involving judgment of sentence meaning (Gollob, 1968; Healy & Miller, 1970; Heise, 1969; 1970), and in tasks requiring performance under disruption (Gladney & Krulee, 1967).

The verb, in this view, provides the relational framework for the sentence. Therefore it seems reasonable that the verb should determine which classes of nouns can fill its argument slots. Chafe (1970, pp. 97-98) makes this prediction. He compares the verb to the sun, in that "anything which happens to the sun affects the entire solar system," whereas "a noun is like a planet whose internal modifications affect it alone, and not the solar system as a whole." Similarly, Healy and Miller (1970) compare the verb to the plot of a play and the nouns to the actors who merely act out the plot. Thus, considerations of verb centrality suggest that the verb semantic structure should govern the semantics of the nouns in a sentence.

Yet informal observation suggests that the opposite pattern often occurs: The verb meaning often adapts to the noun meaning in cases of strain. The first author informally presented many people with the sentence

The flower kissed the rock.

and asked them to report what they pictured in response to the sentence. If fixed verb meaning was the rule, people might have reported a picture of a flower-like person and a rock-like person engaged in a literal act of kissing. Instead, they reported something like "a daisy drooping over a rock, with its petals pressed against the rock," or "a daffodil blown gently across the rock and brushing it lightly." They preserved noun meaning and altered the verb.[1]

This brings us to the central hypothesis of this report, the *verb mutability* hypothesis (Gentner, 1981b): When the noun and verb of a sentence are semantically mismatched, the normal recourse is to make an adjustment to the verb's meaning in interpreting the sentence. Briefly put, in case of mismatch, the verb gives in. Such a claim is, of course, contrary to the verb-centralist prediction that the meaning of the verb should dominate that of the noun. Later in this report, we will consider whether verb-central theories need necessarily imply verb-dominant interpretation strategies.

Plan of the paper. The first requirement in this research is to determine where change of meaning occurs. A major difficulty in carrying out this kind of research is to devise objective tests of change of meaning. Since beginning this research with Albert Stevens in 1973, I and my colleagues have come up with three different methods for measuring change of meaning. Indeed, from a psychological point of view these methodological innovations are among the contributions of this report. However, because readers from other disciplines may wish to skim over the experimental techniques, we have organized the report into three parts. Part I describes experiments designed to test where change of meaning occurs. Part II presents experiments on the nature of the adjustment process. Part III is a summary and theoretical discussion. Readers who wish to touch lightly on the experimental methodology may want to read the rationale at the beginning of Part I, possibly the experiments in Part II, and the theoretical discussion in Part III.

PART I: EXPERIMENTS ON WHERE CHANGE OF MEANING OCCURS

Rationale. In two experiments, subjects were asked to paraphrase simple sentences of the form "The noun verbed." The sentences were composed using all 64 possible pairs in a matrix of eight nouns and eight verbs. (See Figure 1.) Of the eight nouns, two were human, two animate non-human, two concrete, and two abstract, according to the hierarchy discussed by Clark and Begun (1971). (It should be noted that not every step in their hierarchy is used here.) Correspondingly, the eight verbs were divided into two each of verbs preferring for their subject nouns either human, animate non-human, concrete, or abstract nouns.

When the noun and the verb agreed, the sentences were normal-sounding. For example, the verb "limp" prefers an animate subject and "mule" is an animate noun; thus "The mule limped" should be an acceptable sentence. The sentence "The daughter limped" is also acceptable, because "daughter" is animate (and human as well). However, when the nouns violate the verbs' subject preferences, the

sentences are strained. For example, if "limp" is paired with a nonanimate noun such as "lantern," then the resulting sentence, "The lantern limped," is semantically strained.

The verb mutability hypothesis predicts that under semantic strain, subjects will alter the meaning of the verb more than that of the noun in paraphrasing the sentences. To test this, three different measures of change of meaning were applied to the paraphrases:

1. **Divide-and-rate method** (Pilot Study): Judges divided the paraphrases into the part that came from the original noun and the part that came from the original verb; then ratings were collected between the original words and the paraphrase segments that came from them.

2. **Double-paraphrase method** (Experiment 1): A new group of subjects paraphrased the paraphrases. Then we simply counted the occurrences of any original noun or verb in the reparaphrases. The number of original words that resurfaced in these reparaphrases was taken as a measure of meaning preservation. The reasoning is that the more a word's meaning was distorted in the initial paraphrase, the less likely it is that the original word will return in the second paraphrase. For example, the noun *lizard* is more likely than the verb *worship* to return in a reparaphrase of "The small gray reptile lay on a hot rock and stared unblinkingly at the sun."

3. **Retrace method** (Experiments 1 and 2): A new group of subjects was given the eight original nouns (or the eight original verbs). Then they were read the 64 paraphrases. Their job was to guess for each paraphrase which word had occurred in the original sentence. Their accuracy was taken as a measure of the degree of meaning preservation. The reasoning is that the more a word's meaning had been altered in the paraphrase, the harder it should be to retrace that original word.

The results bore out the verb mutability hypothesis. By all three measures, verbs changed meaning more than nouns. Further, this differential was greatest in the semantically strained sentences, indicating that the verb adjustment was a response to the strain, rather than, say, a reflection of some general vagueness in verb meanings.

PILOT STUDY

Paraphrase Task

Method

Subjects. Sixteen subjects, all undergraduates at the University of California at San Diego, participated in the original paraphrase task, receiving class credit in psychology courses.

Materials. Sentences were constructed using nouns and verbs that varied in compatibility with each other. The basic design was the 8 x 8 matrix shown in Figure 1, which led to 64 sentences of the form "The noun verbed."

Each subject paraphrased a set of eight sentences, selected so that no subject received the same noun or verb more than once. There were eight such sentence sets, to make a total of 64 sentences distributed across eight groups of two subjects each. The order in which sentences were paraphrased was randomized for each subject.

[Insert Figure 1 about here.]

Procedure. Subjects were asked to paraphrase the sentences in a natural manner: They were asked to imagine that they had overheard the sentence in passing and were trying to decide the most natural interpretation possible. They were also told not to repeat any content words from the original sentences. Subjects were eliminated if (a) they failed to complete all eight paraphrases; or (b) they used the

original words in the paraphrase in two or more instances; or (c) if they gave two or more patently silly responses, such as "Humpty Dumpty meets King Kong." In fact, most subjects were able to perform the task.

Results

Qualitative examination of the paraphrases suggested that, as predicted, verb adjustment was the dominant strategy of interpretation. When meaning adjustment took place, the meaning of the verb was generally adjusted to fit the meaning of the noun. Other response types also occurred, although infrequently. One was noun adjustment, in which the meaning of the noun was adjusted to fit the verb. A third strategy was to adjust both the noun and the verb. The remaining strategies were even less frequent. The fourth was simple repetition of one word or the other. For example, "The daughter worshipped" was paraphrased as "The daughter prayed to God." Subjects had been instructed not to repeat any content words, so these repetitions were errors, possibly due to carelessness. Repetition errors occurred more often for nouns than for verbs. The fifth response type was pronoun substitution, in which the noun was replaced by a pronoun. For example, the sentence "The mule weakened" was paraphrased as "He became less stubborn." Finally, the sixth response type, which occurred infrequently, was a word-by-word paraphrase that preserved the independent meanings of both words. In sentences with low strain, this led to a reasonable paraphrase; for example, "The lizard limped" was paraphrased as "The small amphibian (*sic*) had an injured leg." On the other hand, for sentences with high semantic strain, the rote strategy led to an unsatisfactory paraphrase; for example, "The lizard worshipped" was paraphrased as "The reptile adored" by one subject. Only a small percentage of the responses fell into the fourth, fifth, and sixth categories, and we will have little to say about them.

The main question from our point of view is whether, when subjects did perform semantic adjustment, the locus of change was the noun or the verb. To obtain objective judgments of relative degree of meaning adjustment, we used a *divide-and-rate* task, as follows.

Divide-and-Rate Task

Division Task

Three upper division, linguistically sophisticated psychology students at the University of California at San Diego, who did not know the hypothesis of the study, read the 128 paraphrases as well as the original sentences. They were asked to indicate for each paraphrase which part came from the original noun and which from the verb. In the cases on which the three judges agreed, their segmentations were then used in a similarity-rating task. Unfortunately, rater agreement was low, so we used only one paraphrase of each sentence in the subsequent rating task. These 64 segmented paraphrases generated 128 similarity judgments, as described below. In seven cases, individual sentence paraphrases that were impossible to score were replaced, using new paraphrase subjects.

Ratings Task

Subjects. A new group of 10 undergraduates from the University of California at San Diego served as raters. They received class credit for their participation.

Procedure. Subjects were read each original noun, along with the corresponding part of the paraphrase (i.e., the part of the paraphrase judged to have come from the noun, and similarly for the verbs). There were 64 noun comparisons and 64 verb comparisons. They were asked to rate the similarity, on a 1-10 scale, for each pair of phrases they were read. For example, they would rate how similar *lizard* was to *small reptile*, or how similar *worshipped* was to *lay on a hot rock and stared unblinkingly at the sun*. Verbs and nouns were randomly mixed in order of presentation. The comparisons were read in a semi-random order, so that pairs involving the same original word were interspersed with other pairs.

Results

The average similarity rating for nouns was 7.6 and the average rating for the verbs was 6.8 (t = 3.73; p < .005). Thus, the noun paraphrases were judged more similar to the original nouns than the verb paraphrases were to the verbs. These results suggest that the verbs changed meaning to a greater extent than the nouns.

Discussion

Although the results of this study were promising, the divide-and-rate methodology had serious drawbacks. First, it was exceedingly time consuming and irritating to the judges. Second, it had the disadvantage that many of the paraphrases had to be discarded because the judges could not agree on which part came from which of the original words. Finally, the judgment was based implicitly on a debatable assumption: that the noun and the verb of the original sentence have separable manifestations in a paraphrase, rather than interacting to produce one unified interpretation. Therefore, for the next study two further methods for judging change of meaning were adopted. These were the *double-paraphrase* measure and the *retrace measure*.

In the *double paraphrase* method, after the initial paraphrases were collected, a second group of naive subjects was asked to paraphrase the paraphrases. Then these reparaphrases were scored for any occurrence of the *original* noun or verb. The relative number of nouns and verbs from the original sentences that resurfaced in these reparaphrases was taken as the measure of meaning preservation. The reasoning is that the better a word's meaning is preserved in the original paraphrase, the more likely the word itself is to return in the second paraphrase.

In the *retrace* measure, new groups of subjects were given the paraphrases and told to figure out which words had occurred in the original sentence. They were given, say, the original eight possible nouns. Then they were read the paraphrases, and for each paraphrase they were asked to circle which noun they thought had occurred in the original sentence from which the paraphrase had been generated. Another group of judges performed the same retrace task for the verbs. The relative accuracy of their choices provided a measure of the relative degree of meaning change in nouns versus verbs. The reasoning here was that the more a word's meaning had been altered in the paraphrase, the harder it should be to trace back to that original word.

The double-paraphrase and retrace measures of meaning change were utilized in Experiment 1. In other respects, this study was a larger scale replication of the pilot study. The basic paraphrase task was identical; the chief difference was in the methodology for judging change of meaning. One important feature of this experiment was that the new methodology, particularly the retrace method, allowed a finer grained analysis of the conditions under which meaning change occurred.

EXPERIMENT 1

Initial Paraphrase Task

Method

Subjects. There were 54 subjects, all undergraduate psychology students at the University of Washington at Seattle. They received credit in psychology classes for their participation. Six of these were eliminated for failure to comply with the instructions (see Pilot Study), leaving 48 subjects.

Procedure. The stimulus materials and method of collecting the original paraphrases were identical to those in the pilot study. Each subject paraphrased eight sentences, chosen so that the same subject never saw a given noun or verb more than once. Thus, eight groups of subjects were required to cover

the matrix of 64 sentences. There were six subjects in each of these eight groups. This meant that there were six paraphrases of each of the original sentences.

Results

Table 1 shows sample paraphrases for normal and strained sentences. Qualitatively, it can be seen that the strained sentences lead to considerable semantic adjustment, particularly for the verb. To verify these patterns objectively, two further tasks were performed. After the original paraphrase had been generated, two new sets of subjects were run on the double-paraphrase task and the retrace task.

[Insert Table 1 about here.]

Double-Paraphrase Task

Method

Subjects. An additional 48 subjects yoked to the original 48 subjects participated. All were undergraduates from the University of Washington, who received class credit for their participation.

Procedure. Each new subject was given the eight original paraphrases written by one of the original subjects, and was told to paraphrase these eight sentences as naturally as possible. These double-paraphrase subjects were given no information as to the original source of the sentences.

Results

The dependent variable was the number of nouns and verbs from the original matrix that reappeared in the reparaphrases. As predicted, nouns outnumbered verbs: 74 nouns (19% of a possible 384) reappeared, as contrasted with 16 verbs (or 4%) ($t = 7.03$; $p < .01$). Thus, by the reparaphrase measure, the degree of change of meaning is greater in verbs than in nouns.

Retrace Task

Method

Subjects. The subjects were 84 college students from the Cambridge, Massachusetts, area, who were paid for their participation.

Procedure. Half the subjects traced nouns; the other half traced verbs. The noun groups were given a list of the eight nouns that had appeared in the original sentences. They were told that they would hear paraphrases generated by other subjects from a set of original sentences, and that each of the original sentences had contained one of the nouns on their sheet. They were not given any information about the verbs in these original sentences. Then they were read each of the 64 paraphrases and told to circle the noun that they thought had occurred in the original sentence on which the paraphrase was based. Parallel procedures were followed with the verb group.

For this task, the original 384 paraphrases were grouped into six coveri[illegible]s, where a *covering set* is defined to be a set of 64 paraphrases that entirely covers the matrix of combinations. To make one covering set requires pooling responses from eight of the original subjects, since each original subject paraphrased eight of the 64 sentences in the matrix. Thus, the original 48 subjects yielded six covering sets. Each of these covering sets was read to a group of seven noun subjects. This meant that there were six groups of seven noun-retrace subjects, or 42 noun-retrace subjects, and similarly 42 verb-retrace subjects.

Combinatorial Patterns

One advantage of the retrace task is that it allows us to go beyond the overall comparison of nouns and verbs and to examine more detailed combinatorial patterns. The matrix of combinations can be divided into three distinct sectors, as shown in Figure 1. First is the diagonal, the matched sector, in which the noun matches the argument specification of the verb.[2] On the diagonal, a verb like *limp*, which calls for an animate subject, is paired with the animate noun *mule* or *lizard*. These sentences (e.g., "The lizard limped") are low in semantic strain. The second sector is the over-matched sector above the diagonal. Here the noun exceeds the argument specification of the verb. The verb *limp*, for example, receives as its subject the nouns *daughter* and *politician*, which are not merely animate, but also human. Sentences in the above-diagonal, over-matched sector should be at least as low in semantic strain as the diagonal sentences.[3] The third sector, below the diagonal, is under-matched. Here the noun fails to meet the subject specifications of the verb. So, for example, the verb *limp*, which calls for an animate subject, is instead combined with a nonanimate concrete noun like *lantern*, or with an abstract noun like *responsibility* to make a sentence like "The lantern limped." This below-diagonal, under-matched sector is the area of greatest semantic strain. Change of meaning should be greatest here, and retrace accuracy lowest.

Results

As Figure 2 shows, the results fit the predictions of the verb mutability hypothesis.

The retrace judgments were considerably more accurate for nouns than for verbs, bearing out the claim that the verb meanings had been more altered in paraphrase than the noun meanings. Further, retrace accuracy is lower for the under-matched (below-diagonal) sector than for the other two sectors. Finally, the interactions, discussed below, indicate that verb change of meaning is greatest where semantic strain is highest.

A mixed-measure analysis of variance[4] was performed over the responses of the 84 retrace subjects. The variables were form-class (noun versus verb, between subjects), matching (matched, over-matched and under-matched, within subjects), and covering-set (the six complete sets of paraphrases each generated by a group of eight original subjects, a between-subject factor).[5] The design was thus Form-Class(2) x Covering-Set(6) x Matching(3). The results were quite strong. There are main effects for form-class, confirming that nouns were better retraced than were verbs ($F(1,72) = 220.28$, $p < .0001$), and matching, confirming that retrace accuracy was lowest in the under-matched sectors ($F(2,144) = 103.43$, $p < .0001$). The interaction between form-class and matching was also significant ($F(2,144) = 23.8664$, $p < .0001$). This interaction is important, for it reflects the fact that the retraceability difference between nouns and verbs was greatest in the under-matched sector. That is, verbs change meaning most when semantic strain is greatest.

There was also a main effect of covering-set ($F(5,72) = 8.30$, $p < .0001$), and all interactions with covering-set were significant. We take this to mean either that there were differences among the specific original paraphrases or the specific groups of retrace subjects or both. Such differences are not surprising in complex psycholinguistic tasks, and they do not alter the main findings.

[Insert Figure 2 about here.]

Discussion

One useful feature of the experiment so far is the opportunity to compare three measures of change of meaning. Our initial method, the divide-and-rate method, was straightforward in its logic: The idea was simply to find the part that came from the noun and the part that came from the verb and ask which differed more from the original word meaning. But this method turned out not to be straightforward in practice, since the raters could not agree on "the part that came from the noun (or verb)." Therefore

two new methods were devised. Though more indirect in their logic, the retrace and double-paraphrase methods actually turned out to be far less problematical than the divide-and-rate method. Like the divide-and-rate method, these new methods still require running two sets of subjects for every result. The key difference is that all the tasks involved are intuitive for subjects. This means that they do not require the discarding of large amounts of data and that we can have more confidence in the data we collect. A key point here is that all three methods led to the same conclusions. Therefore we now have converging methods of assessing change of meaning.

The three measures of change of meaning used in the pilot study and in Experiment 1 all produced the same results: that under semantic strain the primary locus of change is the verb. They also indicate that the adjustment in verb meaning is orderly. The patterns of change indicate that the verb preserved its meaning insofar as possible. Given a compatible noun, the verb was paraphrased in a way that preserved its meaning; but given an incompatible noun, the verb meaning was adjusted to fit. Our subjects appeared to treat the nouns as referring to fixed prior entities, and the verbs as conveying mutable relational concepts to be extended metaphorically if necessary to agree with the nouns. However, before drawing conclusions, we must consider another possible interpretation. It could be that the patterns of mutability stemmed simply from word-order conventions, rather than from form-class differences. In the sentences used, the noun preceded the verb and served as topic. Perhaps the differences between nouns and verbs can be attributed to given-new strategies based on the order of information (Clark & Haviland, 1977). Thus in the sentence "The lizard worshipped," lizard, being first, was the given, and hence more likely to be taken as fixed. To check this possibility, in Experiment 2 the word order was changed so that the verb occurred first. All sentences were of the form "Worshipped was what the lizard did." Otherwise, the procedure, including the set of nouns and verbs used, was as in Experiment 1. Again paraphrases were collected, and again these paraphrases were subjected to further manipulations in order to gain a measure of change of meaning. Because the retrace task allows investigation of where the greatest change of meaning occurred, we used the retrace task to gauge change of meaning.

EXPERIMENT 2

Paraphrase Task

Method

Subjects. There were 53 subjects, all undergraduate psychology students at the University of Washington who received class credit for their participation. Five of these were eliminated for failure to comply with the instructions (see Pilot Study), leaving 48 subjects.

Materials. As in Experiment 1, there were 64 sentences corresponding to the 64 noun-verb combinations. These were divided into eight sets of eight such that each subject paraphrased eight sentences, with no noun or verb repeated. Sentences had the form "Verbed was what the noun did" (e.g., "Worshipped was what the lizard did").

Procedure. The procedure for the original paraphrase task was identical to that used in Experiment 1.

Retrace Task

Method

Subjects. The subjects were 84 college students from the Cambridge, Massachusetts, area, who were paid for their participation.

Procedure. The procedure was as in Experiment 1. The noun-retrace subjects heard the paraphrases and circled which of the original nouns they thought had been in the sentence, and similarly for the verb-retrace subjects.

Results

Again, the results were as predicted by the verb mutability hypothesis. Figure 3 shows that the proportion correct in the retrace task was considerably higher for noun-retrace than for verb-retrace subjects.

[Insert Figure 3 about here.]

Moreover, the retrace disadvantage for verbs is greatest in the under-matched sector.

A mixed-measure analysis of variance was performed over the responses of the retrace subjects. As in Experiment 1, the variables and design were Form-Class(2) x Covering-Set(6) x Matching(3). There was a main effect of form-class ($F(1,72) = 254.72, p < .0001$), confirming that verbs were less accurately retraced than nouns. There was also a main effect of matching ($F(2,144) = 82.27, p < .0001$), confirming that the greatest distortion was in the under-matched sectors. The key interaction between form-class and matching was again significant ($F(2,144) = 28.16, p < .0001$), confirming that the mutability difference between nouns and verbs is greatest in the under-matched sector, the area of greatest semantic strain. As in Experiment 1, the main effect of covering-set was significant ($F(5,72) = 4.50, p < .001$) and all interactions with covering-set were significant, again indicating differences in the original paraphrases and/or the retrace groups.

PART II: EXPERIMENTS ON WHAT KINDS OF MEANING CHANGE OCCUR

Experiments 1 and 2, and the Pilot Study, produce a clear convergent pattern of results. First, when a semantic adjustment is effected, the verb is the primary locus of change. These results support Gentner's (1981b) verb mutability hypothesis: in case of conflict, the verb gives in to the noun. A second important finding is that in Experiments 1 and 2 we obtained a gradient of verb adjustment from sentences of low semantic strain to sentences of high semantic strain. The verb disadvantage in retraceability is greatest in sentences with high semantic strain. That is, the greatest changes in verb meaning occur in the sentences of greatest strain: that is, in the under-matched sector. This suggests that verb meaning adjustment is selective and systematic.

Overall, the results of Experiments 1 and 2 indicate that the verb is the locus of change in a sentence when semantic strain forces meaning adjustment, and that the greater the strain, the greater the adjustment. Now we ask how these adjustments occur. Experiments 3a and 3b were designed to examine more closely the mechanisms of change of meaning. In order to permit a closer analysis of the mechanisms, we limit the verbs to a subset of the verbs of possession. By comparing verbs that share the same stative, that of *possession* (Rumelhart & Norman, 1975), we can more closely examine which components are preserved and which are altered when subjects interpret the sentences. The verbs of possession were chosen because they have been studied previously (Bendix, 1966; Fillmore, 1968; Gentner, 1975; Schank, 1972).

Experiment 3a was conducted with several goals in mind. First, it was intended to extend the locus-of-change results of Experiments 1 and 2 to *object* nouns as described below. Second, it provided an initial examination of the processes by which change of meaning occurs. Third, it yielded initial stimuli for a planned choice task (Experiment 3b). As in Experiments 1 and 2, we gave subjects sentences to paraphrase as naturally as possible. To allow us to generalize the verb mutability phenomenon, there were some changes from the materials of the first two experiments. First, the verbs used were a set of eight possession verbs, such as *borrowed* and *bought*. Second, the sentences were of the form "Sam borrowed a vase," or "Sam bought a doctor," so that the key noun was the *object* noun instead of the subject/agent noun. This allowed us to check on whether the verb mutability results in Experiments

1 and 2 reflect general verb-noun interactions, or are specific to interactions with subject or agent nouns. (Recall that in Experiment 2, even though the sentences used verb-first word order [e.g., "Worshipped was what the lizard did."], the noun [e.g., *lizard*] retained its role as the agent or experiencer.)

In Experiment 3a, all the subject nouns were proper names; the experimental manipulation concerned only the object slot. Thus, subjects paraphrased sentences like "George bought doom," where the question was whether *bought* would be altered more than *doom*. The nouns used as objects were either concrete nouns (e.g., *vase*), nouns denoting human occupations (e.g., *doctor*), or abstract nouns, either positive (e.g., *luck*) or negative (e.g., *doom*). We predicted that the concrete nouns would produce low-strain phenomena, and that the human and abstract nouns used as objects of possession verbs would produce high-strain phenomena. That is, verbs would alter meaning more when paired with human and abstract objects than when paired with concrete objects. We further predicted that, as before, subjects would attempt to preserve as much of the verb's meaning as possible. Beyond this, we wished to investigate whether there would be any pattern as to *how* the verb meaning would be adjusted.

EXPERIMENT 3A

Method

Subjects. Subjects were 16 University of Illinois undergraduates who were paid for their participation.

[Insert Figure 4 about here.]

Materials. Sentences were constructed from a set of eight verbs of possession and eight nouns that served as direct objects. The matrix from which the sentences were generated is shown in Figure 4.

All sentences were of the form "X verbed the object." Sentence subjects were masculine proper names (e.g., "Arnold stole a book"). There were eight such names, counterbalanced across the verb and object combinations. The eight object nouns consisted of two concrete nouns (*book* and *vase*), two human nouns (*doctor* and *mechanic*), and four abstract nouns; two abstract+ nouns with positive connotations (*luck* and *loyalty*) and two abstract- nouns with negative connotations (*poverty* and *doom*). All nouns except the concrete nouns resulted in nonliteral sentences, which were predicted to be relatively high in semantic strain.

Sentences were constructed from this matrix in the same manner as in the previous experiments, making 64 sentences. Sixteen filler sentences were also included. The filler sentences were syntactically similar to the test sentences. They consisted of a masculine proper first name, a verb and a direct object. Of the filler sentences, 6 contained verbs of possession not used in the study (e.g., "Paul received a clock") and 10 contained other randomly chosen verbs (e.g., "Patrick spilled paint"). None of the filler sentences containing verbs of possession violated a selectional restriction of the verb. The filler sentences were included chiefly to keep subjects from falling into a pattern of expecting odd sentences.

Procedure. The procedure was the same as that used in Experiments 1 and 2. Each subject paraphrased 8 stimulus sentences interspersed with 16 filler sentences for a total of 24 paraphrases.

Qualitative Scoring. One rater judged the sentences and scored the type of adjustment strategy used.[6]

Results

Results again showed that verbs exhibited more change of meaning than did nouns. Figure 5 shows the adjustment strategies used by paraphrase subjects.

[Insert Figure 5 about here.]

Verb adjustment occurred much more frequently than did noun adjustment. Further, although it often happened that verb meanings were changed while noun meanings were left intact, nouns seldom changed meaning without a concomitant change in verb meaning. The same range of alternate paraphrase strategies was seen as in Experiments 1 and 2; the only exception was rote word-by-word paraphrase, which was a frequent strategy for literal sentences. The proportion of rote responses was .16 for concrete object nouns, and .02 for each of the nonliteral cases--human, abstract+ and abstract-. As in the previous experiments, pronoun substitution and repetition of original words were very rare.

Examination of the paraphrases suggests that subjects treated the strained sentences as requiring metaphorical extensions of normal verb use. The pattern of verb adjustments suggests systematic processes underlying these metaphorical extensions. When interpreting the semantically strained sentences, it seems that subjects tended to retain some of the structure of the verb. What changed was the domain of discourse of the verb. For example, a verb that normally conveys a causal change of possession (e.g., *discard*) would be interpreted as a causal change in some other dimension. The sentence "Marvin discarded a doctor" was paraphrased as "Marvin consulted a different practitioner of medicine." Note that in this paraphrase there is no loss of *possession*, but rather a loss of the *services* of Marvin's current doctor. The causal change of state remains, and with it the fact that it was Marvin who initiated the change of state, but the notion of ownership is lost. Similarly, "Bill owned luck" was paraphrased as "Bill always has good things happen to him." Again, the state of possession is not retained in the paraphrase, although the notion of an enduring state of events is. Bill does not continue to *possess* luck, but he continues to *experience* lucky events. These responses appear to reflect an orderly, rule-governed process, rather than an ad hoc attempt to make sense from nonsense.

Discussion

One purpose of Experiment 3a was to generate stimulus materials to use in a choice task. Experiment 3b used a forced-choice task in order to establish tighter experimental control and to eliminate the problem of the subjective interpretation of paraphrase data. It sought more closely to examine the process of verb metaphorical extension. With this task we hoped to obtain objective data on the kinds of semantic adjustments that occur. Before proceeding to Experiment 3b, let us review our findings so far.

Initially, it seemed that four possible views might exist as to what happens under semantic strain. First is the *normative view*, which holds that sentences that violate matching restrictions are seen as nonsensical and will either be rejected as uninterpretable or, at best, will show no systematic interpretation patterns. Although this view may seem a straw man, it is important to rule it out. So far the evidence from Experiments 1-3a argues against this position. Subjects did not reject the strained sentences, instead showing a dominant strategy of altering the verbs' meaning. However, the forced-choice task will provide a clearer test. If, as in the normative rules view, the stimulus sentence is wholly meaningless, no one response will be preferred. There should then be a random response pattern in the forced-choice task.

Views 2-4 are all versions of semantic adjustment processes. View 2 is the *radical subtraction* view: that when faced with a violation of selectional restrictions, people discard the meaning of the verb, retaining only a general sense of what verbs tend to mean. Thus a given verb, such as a verb of possession, would be distilled to a general change of state, but would lose all other aspects of its meaning. View 3, related to the previous view, is the *pragmatic amplification* view. Once it is clear that the literal meaning of the verb will not work, people might make sense of the nonliteral sentences by first suspending all or most of the usual meaning of the verb and then constructing a plausible scenario. This view emphasizes the role of pragmatics in metaphorical extension (e.g., Searle, 1979). In practice, this account is a combination of radical subtraction plus pragmatic amplification. First, the verb is reduced to a general change of state, and then context determines the amplification.

Views 1-3 have in common a kind of simplicity in the adjustment processes they postulate. Sentences that violate the verb's semantic restrictions are rejected outright in the strong normative view. In the radical subtraction view, such sentences will have their verbs reduced to simple changes of state--effectively, to dummy verbs that convey little specific information except that something happened. Finally, in the pragmatic amplification view, after a radical subtraction step, context may be used to fill in the intended verb.

View 4, the *minimal subtraction* view, differs from the other three in postulating greater semantic specificity in the mechanisms of adjustment. In this view, subjects interpret the sentences by making minimal semantic adjustments to the verb. According to this minimal subtraction view, people interpret the sentences by performing the minimal necessary adjustments in verb meaning, rather than by postulating a general change of state and/or substituting contextual information.

The response choices for Experiment 3b were designed to reflect these four strategies. These responses were based in part on subjects' paraphrases in Experiment 3a, with the constraint that each sentence have four response choices as follows.

1. **Minimal Subtraction.** The Minimal Subtraction choice preserved the verb's meaning as closely as possible. In the literal sentences, it was simply a rote paraphrase. Thus, for the sentence "Randy stole a vase," the Minimal Subtraction response was "Randy illegally took a flower holder that didn't belong to him." In the nonliteral sentences, a minimal change was made in the verb's meaning to produce a plausible metaphorical meaning. For example, the Minimal Subtraction response for the sentence, "Chuck stole a plumber," was "Chuck hired a plumbing specialist away from another employer."

2. **Radical Subtraction.** In the Radical Subtraction choice, all components of the verb meaning, except for the change of state, were subtracted. This interpretation was correct, but extremely underspecified. For the example sentence, "Chuck stole a plumber," the Radical Subtraction response was "Chuck had a plumbing specialist do some work for him." Here, the verb borrowed is reduced to a simple change of state.

3. **Pragmatic Amplification.** The Pragmatic Amplification choice assumed some significant suspension of the verb's usual meaning, but also added additional contextual information designed to make the sentence plausible. For example, for "Chuck stole a plumber," the Pragmatic Amplification response was "Chuck paid a very high salary and hired away his rival's best plumbing specialist."

4. **Control.** The Control choice was irrelevant to the meaning of the original sentence; however, it contained concepts associated with some of the original concepts. The Control response for "Chuck stole a plumber," was "Chuck lived by the beach and had a tool box." This choice was included as a test of the strong normative claim that nonliteral sentences are completely uninterpretable. If this were true, all four responses would be viewed as equally anomalous, and in particular the Control response would be chosen equally as frequently as the other responses. In addition, this choice served to check whether subjects were indeed interpreting the sentences.

EXPERIMENT 3B

Method

Subjects. Subjects were 48 University of Illinois undergraduates, who participated in the experiment as part of a course requirement.

Materials and design. Sentences for this experiment were similar to that used in Experiment 3a, with a few exceptions. First, the verbs owned and traded were eliminated to reduce the number of stimuli. This left the verbs *kept, bought, borrowed, stole, lost,* and *discarded*. The objects were of the same basic

types as in Experiment 3a. However, because no differences were found between abstract+ and abstract- nouns, this distinction was eliminated. Thus three types of object nouns remained: concrete objects that resulted in literal sentences, and human and abstract nouns that resulted in nonliteral sentences. Six object nouns of each type were selected. The subject nouns were men's first names; a unique name was chosen for each sentence. The matrices from which the sentences were constructed are shown in Figure 6.

Note that the matrices for concrete and abstract objects were analogous. For concrete objects, the top row was *book, vase, lamp, chair, hammer,* and *coat*. For abstract objects, the top row was *luck, loyalty, poverty, doom, freedom* and *despair*. Note that these matrices are slightly different from those of Experiments 1 and 2. First, they are 6 x 6 instead of 8 x 8; second, *three* matrices were used here instead of one (although all three involved the same verbs). Third, each matrix contains six nouns of the same type--concrete, human, or abstract. This study tests each kind of verb-noun combination more thoroughly than in previous studies.

[Insert Figure 6 about here.]

Every sentence was followed by the four response choices: the Minimal Subtraction response, the Radical Subtraction response, the Pragmatic Amplification response, and the Control response. Sample stimuli are shown in Table 2. The order of the choices was varied randomly. There were also 12 filler sentences, each with four response choices.

As in Experiment 3a, sentences were generated by combining the verbs and object nouns from each matrix, with proper names as subject nouns. Each subject saw all six verbs three times, once each with a noun of each of the three object types, for a total of 18 stimulus sentences per subject. In addition, each subject saw 12 filler sentences, making a total of 30 sentences. To counterbalance any specific association of verbs with objects, a Latin Square was used. Two orders of presentation were used, one the reverse of the other. In each order, we imposed the constraint that a verb could not appear within two items of itself. Six subjects were required to cover the three matrices fully. Since we had 48 subjects, the matrices were covered eight times--four times in each of the two orders of presentation.

[Insert Table 2 about here.]

Procedure. Subjects were given booklets containing two sentences per page. Each sentence was followed by four possible interpretations. Test sentences were interspersed with filler sentences. Subjects were told to imagine that while walking through a cafeteria, they overheard someone saying the stimulus sentence. They were to choose the response that they thought best reflected the meaning a speaker might have intended by the sentence.

Results

The proportion of responses of each type across all sentences is shown in Figure 7. It can be seen that the Minimal Subtraction response was chosen substantially more often than the others. After the Minimal Subtraction, the next most frequent response was the Radical Subtraction response in which only the change of state is preserved. Subjects rarely chose the Pragmatic Amplification response, and almost never chose the Control response.

These differences were confirmed with t-tests. All differences between adjacent pairs of responses were significant. For the frequencies of the Minimal Subtraction and Radical Subtraction, $t(47) = 11.36$, $p < .001$. For the Radical Subtraction and Pragmatic Amplification responses, $t(47) = -.32$, $p < .001$. Lastly, for the Pragmatic Amplification response and the Control response, $t(47) = 6.39$, $p < .001$.

So far we have discussed results across all sentences. Figure 8 shows the results for the semantically strained sentences (i.e., sentences with human or abstract objects instead of concrete objects). Again,

the Minimal Subtraction response was by far the most frequently chosen response. T-tests for the frequency of response choices confirmed that Minimal Subtraction was chosen significantly more often than its nearest competitor, Radical Subtraction for both human and abstract objects ($t(47) = 6.32$, $p < .0001$; $t(47) = 4.07$, $p < .0001$, respectively). All other adjacent pairs were significantly different, with the exception of Pragmatic Amplification versus Radical Subtraction for human objects.

[Insert Figures 7 and 8 about here.]

In order to test the differences between different types of objects, four one-way analyses of variance were calculated across the four types of objects, one for each response type. The Minimal Subtraction response, the Radical Subtraction response, and the Pragmatic Amplification response all varied significantly across object type.[7] ($F(2,141) = 20.590$, $p < .001$), and ($F(2,141) = 11.488$, $p < .001$) and ($F(2,141) = 5.666$, $p < .01$ respectively). This was not true for the Control response. There was no significant difference in frequency across object types for control responses.

To sum up, the Minimal Subtraction response was preferred overwhelmingly by subjects both on the literal and the nonliteral sentences. This response retains as much of the literal meaning as possible, removing only the components necessary to make sense of the sentence. After Minimal Subtraction, the next most frequent response was the Radical Subtraction response. This strategy reflects a kind of "starting up from the ground" strategy in which only the change of state is preserved. The other two responses were rarely chosen. The fact that subjects almost never chose the Control response corroborates other evidence in ruling out the *normative* view, which predicts that since the nonliteral sentences are nonsensical, subjects should choose randomly among the available responses. Finally, subjects rarely chose the Pragmatic Amplification response.[8]

PART III: GENERAL DISCUSSION

Summary of Research

This research concerns the combinatorial rules for verbs and nouns. Experiments 1 and 2 investigated the locus of change of meaning. Subjects paraphrased sentences in which the noun and the verb were either semantically matched or semantically mismatched. Using three different tests of change-of-meaning, we found that the verb changed meaning more than the noun. This was true whether the verb occurred in its normal position (e.g., "The lizard limped") or in initial position (e.g., "Limped was what the lizard did"). The results were orderly: The degree of meaning change reflected the degree of semantic strain.

Experiments 3a and 3b extended the verb mutability results to verb + object sentences and investigated how this meaning adjustment occurs. We considered a range of interpretation strategies, varying in the specificity and complexity of the processes. The least complex was the Radical Subtraction view. In this view, in case of strain, people should preserve only the most general information about the verb--that it conveys, say, a change of possession, or possibly simply a change of state. A related possibility is that after such subtraction, people make sentences interpretable by amplifying the event with pragmatic information not specified by the verb's literal meaning. Finally, the most complex and semantically specific possibility considered is that people effect a minimal semantic adjustment in the verb's meaning: They subtract and replace the minimum number of aspects of the verb's meaning necessary to produce a coherent interpretation. The results support this Minimal Subtraction position.

The finding that people make a minimal semantic adjustment rather than the radical subtraction adjustment is in some ways surprising, since the minimal semantic subtraction strategy requires the person to use considerably more information in effecting the semantic adjustment. Since these metaphorical extensions often appear to occur without much effort, one might have expected the simpler radical subtraction strategy to have been adopted. It appears that a rather fine-tuned semantic adjustment provides the best account of the comprehension of novel noun-verb combinations. Change

of meaning does occur to accommodate contextual constraints, but our findings suggest that the change involves computations over the internal structure of the verb. Using the language of componential representation, we conjecture that people try to preserve as many components of verb meaning as possible.

Why Verb Adjustment

Why should the verb adjust more than the noun? Several mechanisms suggest themselves.

1. **The verb is outnumbered by nouns.** As discussed above, in interpreting the sentence "The flower kissed the rock," subjects normally preserve noun reference and alter the verb's meaning to fit the noun meanings. But here there are two concrete nouns as against one verb. Perhaps the verb's normal meaning, with its preference for animate arguments, is simply overridden by sheer numbers. Cottrell and Small (1983) discuss such a 'voting' mechanism in a connectionist framework. For example, the verb "throw" in "Bob threw a ball," would be interpreted as meaning *propel*, largely because this sense of "throw" is compatible with the most frequent meaning of the noun "ball" (a *spherical toy*). But in "Bob threw a ball for charity," the noun "charity" joins with the secondary sense of "ball" (a *dance*) and this coalition of two nouns shifts the meaning of "throw" from its *propel* sense to its *give-an-event* sense. Of course, with such a summation-of-activation mechanism, the verbs can vote too. In a sentence like "Bob kicked and threw the ball for charity," the *propel* sense of the verb would presumably again be dominant. But since multiple-noun sentences are more common than multiple-verb sentences, this voting mechanism will in general act to favor verb mutability.

This mechanism seems highly plausible and must surely account for some of the verb mutability effect. But it is not sufficient to explain the whole phenomenon, as our experiments indicate. In Experiments 1 and 2 we pitted one subject noun against one verb, and in Experiments 3 a-b we pitted one object noun against the verb (leaving the subject noun an inert proper noun). In all cases there was a substantial verb mutability effect. Therefore outnumbering cannot be the only explanation.

2. **Polysemy is greater for verbs than nouns.** Verb mutability may be related to another interesting characteristic of verbs: their relatively high degree of polysemy. Verb polysemy is easy to observe for frequent verbs; verbs like have, move or make can have dozens of meaning senses. We can have 10 dollars, but also a bad dream, a lame leg, a cold, a pleasing personality, and so on. Gentner (1981b) compared the number of dictionary meaning senses for words of different form classes across four different levels of word frequency. Across all classes, more frequent words have greater numbers of meaning senses (Zipf's Law). However, at all frequency levels, verbs have substantially more meaning senses than nouns. Indeed by this measure, verbs have greater breadth of meaning than any other form-class (with the single exception of prepositions in the highest frequency sample). Perhaps it is the greater degree of verb polysemy that accounts for the verb mutability effect. The fact that a given verb has several associated meanings means that the hearer has more options to choose from for verbs than for nouns in selecting the meaning sense that best fits a context. There is a considerable body of research showing effects of context in selecting among multiple word senses of a given word (e.g., Anderson & Ortony, 1975; Swinney, 1979; Tanenhaus, Leiman, & Seidenberg, 1979). Moreover, in parallel systems such as that of Cottrell and Small (1983), the proliferation of meaning senses will tend to mean that any one sense will have rather low initial activation and thus can easily be overcome by a dissenting noun.

Verb polysemy almost surely provides one route to contextual adaptability. However, we do not believe that it can account for the whole phenomena of verb mutability. In particular, it cannot account for the results presented here. By design, many of our sentences elicited interpretations that could not plausibly have been included in the verb's existing list of senses. For example, in "The lizard worshipped," it is unlikely that the verb "worship" included *stared at the sun* among its prior word senses. People's ability

to deal with novel combinations seems to go beyond simply selecting from a range of prestored verb meanings.

The more interesting issue, in our view, is the reverse causality between mutability and polysemy. If we ask how polysemy comes about historically, one plausible way in which a word could accrue meaning senses over time is by being relatively mutable. As its meaning is reinterpreted in different sentence contexts, some of these reinterpretations occur often enough to be remembered. The end result of the gradual accretion of contextually adapted meaning-variants would be a high degree of polysemy. In this way, verb mutability could provide a mechanism for the greater degree of verb polysemy.[9]

3. **Operators versus referential terms.** Verbs function as predicates over objects, while nouns serve to establish reference to individual objects (including conceptual objects). That is, verbs have the job of conveying relations or events that apply to the referents established by the nouns. The conjecture is that part of the mutability effect stems from carrying out the role of operator. One line of evidence for this claim is that in noun-noun sentences, the predicate noun (which functions as operator) typically adapts its meaning to the subject noun (which functions to establish object-reference) (Gentner, unpublished data, 1985).[10] Thus "The acrobat is a hippopotamus," conveys a clumsy acrobat, while "The hippopotamus is an acrobat," conveys an agile hippopotamus.[11] However, the degree of change of meaning for predicate nouns is not as great as we see for verbs, indicating that functional differences are not the sole explanation for the verb mutability effect.

4. **Relative semantic cohesion.** Outnumbering and greater verb polysemy can account for some of the phenomena. But we must invoke internal semantic interactions to account for the full range of verb mutability phenomena. Gentner (1981b) speculated that part of the explanation for verb semantic mutability might be that the representations of many noun concepts (in particular, object concepts) are more internally cohesive, or dense, than comparable verb representations:[13]

> Representations of object-concepts are more internally dense than representations of relational concepts: That is, the ratio between the number of internal links and the number of components linked is greater for object concepts than for relational terms . . . . Because external links allow context to push towards new interpretations, whereas internal links make for a stable interpretation of the conceptual component, verbs should be more adjustable than nouns. (pp. 171-175)

This suggestion has much in common with prior proposals by Langacker (1987) and Wilks (1977, 1978) as well as with some of the proposals currently under investigation in parallel architectures. We do not attempt here to flesh out this proposal computationally. Instead we consider the psychological question of which aspects of the verb's meaning are most likely to be altered.

Modeling Verb Adjustment

Our findings suggest that change of meaning may be a process of graded compromise in which some parts of the verb's meaning are more resistant than others. More specifically, we conjecture that verb adjustment is structurally ordered such that domain-specific components are the first to give way under semantic strain. We will model these processes using a componential representation of verb meaning. We use the representational format of the LNR notation (Abrahamson, 1975; Gentner, 1975; Norman & Rumelhart, 1975; Rumelhart & Norman, 1975). Related models of verb semantics have been proposed in the format of generative semantics (e.g., Chafe, 1970; Jackendoff, 1976; Lakoff, 1970; McCawley, 1968; Talmy, 1976, 1980), procedural semantics (Miller & Johnson-Laird, 1976), preferential semantics (Wilks, 1977) and conceptual dependency (Cater, 1987; Schank, 1972). (See Munro, 1975, for a comparison.) However, the LNR model has the advantage that the stative is explicitly represented. For example, in representing a possession verb such as "give," CD would represent the change-of-possession as one notion: ATRANS (Agent, Object, Recipient). The LNR notation is more analytical and uses change from an initial state of possession to a final state of possession: CHANGE [POSS

(Agent, Object), POSS (Recipient, Object)]. As discussed below, this is helpful in modeling verb metaphorical extension.

Figure 9 shows a structural representation of the meaning of the verb *give*. In a literal sentence, such as

Ida gave Sam a vase.

all the normal semantic relations specified by the verb *give* are maintained. We know that Ida once had possession of a vase, that she volitionally caused Sam to gain possession of it, and that as a result Ida no longer has the vase, but Sam does. What happens in a nonliteral sentence? For example, consider the sentence

Ida gave Sam a cold.

If we replace *vase* with the object noun *cold*, it is clear that some adjustments are necessary. Ida has not lost *possession* of the cold by transferring it to Sam. Instead, there has been a change in Sam's state of *health*. Although the possession component must be altered, some of the higher order aspects of the verb *give* are maintained. Ida has still caused a change of state for Sam, although now the dimension of change is not ownership, but a state of health.

[Insert Figure 9 about here.]

To extend this idea further--that what is altered in a verb metaphorical extension is the dimension along which a change of state occurs, let us consider another example:

The moon gave the lake a silvery sheen.

Again, there has been no transfer of possession. The moon did not own the silvery sheen, nor did it transfer that ownership to the lake. Yet we clearly understand what is intended: The moon has caused a change in the color of the lake. What seems to be retained here from the ordinary meaning of give is a causal change of state. Only the nature of the dimension or state has to alter to accommodate the context. The rest of the verb's structure, particularly the higher order DO-CAUSE-CHANGE structure, is retained. Thus, it is the domain-specific components--the bottom-level components in our diagram--that have changed. We believe this is a rather general strategy in verb metaphorical extension. The components that specify the particular change of state are easily overridden by the surrounding nouns, but the verb retains as much of its higher order structure as possible.

If these kinds of semantic adjustment processes occur, we might expect to find greater comprehension times for sentences with semantic strain (though the exact predictions would of course depend on which aspects of the process were modeled as parallel). Ongoing research by Brown, Marslen-Wilson, and Tyler, using an on-line word monitoring task, provides some support for this prediction (Brown, personal communication, July 1986, Nijmegen, The Netherlands). They find that subjects take longer to process anomalous verb-noun combinations than normal combinations. Purely pragmatic violations (e.g., "The man buried the guitar") take slightly longer to process than normal sentences (e.g., "The man carried the guitar"). However, it is noteworthy that semantic violations lead to still longer processing times than pragmatic violations. Semantic anomalies--violations of selectional restrictions, similar to those used here (e.g., "The man drank the guitar")--require more processing time than pragmatic violations. There is a further increase in processing time for violations of subcategorization rules, a more severe grammatical violation than the ones used here (e.g., "The man meditated the guitar"). Thus there is some promising evidence for processing-time correlates of the kinds of semantic adjustment processes proposed here.

Lakoff and Johnson (1980) document many examples of metaphorical extension of verbs and other relational terms. Spatial relations are particularly productive (Nagy, 1974; Reddy, 1979). For example, to say that someone is *going to perdition* or *getting into trouble* does not convey any change in physical location, but rather a change of fortune or state of well-being. In this way, verb metaphorical extension has much in common with analogy (Kittay & Lehrer, 1981). In both cases, it is the lower order concrete information that is suspended (Gentner, 1981b, 1983). Indeed, in a sense verbs are institutionalized analogies.[13] They are devices for conveying relational structures independently of the concrete objects to which the structures are applied.

Verb Centrality

The results of Experiments 1-3a supported the verb mutability hypothesis: When a sentence exhibits semantic strain, the primary locus of change of meaning is the verb. Further, although there is little prior research on this direct question, our findings are consistent with a developmental finding by Reyna (1980): Children given semantically strained sentences tended to prefer interpretations in which the verb's meaning was altered to fit the noun rather than the reverse.

These findings seem to run counter to the predictions of a verb-central position. Verbs have often been regarded as providing the relational framework for the event (e.g., Chafe, 1970) (see also Figure 9). In case grammar, it is the verb which specifies the case relations that relate the nouns to the central event (Fillmore, 1966; 1968; 1970; Healy & Miller, 1970). Many grammars have successfully used verb-centered representations (Bresnan & Kaplan, 1975; Chafe, 1970; Fillmore, 1966; 1968; Kintsch, 1974; Norman & Rumelhart, 1975; Schank, 1973; 1974). A natural conclusion is that if the verb provides the central frame for sentence meaning, it should be the most important and stable element. Our data indicate that verbs may, on the contrary be among the more mutable elements of the sentence.

On deeper consideration, we believe that it is possible to reconcile the valuable insights of the verb centralist approach with the phenomenon of verb mutability. That verbs function as central organizers of a sentence need not imply that they are semantically more stable than nouns. Indeed, Gentner (1981b) suggested that the mutability of verbs may arise in part from their function as a central organizer. In this view, nouns normally act to fix reference and the verb acts as an operator over the noun meaning(s). The verb's function is to link the nominal concepts into one coherent assertion, and this may mean suspending one or more of its own normal components in case of conflict between a noun argument and the verb's usual semantic structure. In particular, one relatively economical way to achieve coherence is for the lower order, domain-specific components of the verb to be suspended or replaced. Thus, verb mutability may in part result from verb centrality.

Conceptual Combination

In addition to its connections with psycholinguistic models of semantic processing, this research bears on the issue of conceptual combination (Hampton, 1988; Osherson & Smith, 1981, 1982; Medin & Shoben, 1988; Smith & Osherson, 1984; Smith, Osherson, Rips, Albert, & Keane, 1988). This work is done from a cognitive rather than linguistic point of view. The major issue is how the intension and extension of a combination of two concepts relate to the intensions and extensions of the two separate concepts. Among the most detailed of these models is that of Osherson and Smith and their colleagues on noun-adjective semantic combination (Osherson & Smith, 1981, 1982; Smith & Osherson, 1984; Smith, Osherson, Rips, Albert, & Keane, 1988). They demonstrate that the typicality of an item as a member of a combination cannot in general be predicted from its typicality as a member of the two separate concepts. For example, a guppy is highly typical as a *pet fish*, even though it is low in typicality as a *pet* and as a *fish*. It appears that something more is required than a simple additive or averaging operation on the external dimension of typicality. Rather, this research suggests that the internal featural representations of the concepts must be used in the combinatorial calculations.

Briefly, Osherson and Smith model nouns (e.g., *apple*) as having a list of independent attributes. An adjective (e.g., *brown*) selects a dimension (e.g., *color*), specifies a value (*brown*) on that dimension and increases the diagnosticity of its dimension, so that color is more important in a *brown apple* than in an ordinary unmodified *apple*. Conjunctions may be either positively diagnostic (e.g., *red apple*), nondiagnostic (e.g., *unsliced apple*), or negatively diagnostic (e.g., *brown apple*). Interestingly, it is on the negatively diagnostic conjunctions, like *brown apple*, that the simple combination-of-typicality model fails most severely. That is, the more a conjunction violates normal expectations, the more the typicality of the conjunction diverges from a simple combination of the typicalities of its constituents.

There are important parallels between our work and that of Osherson and Smith (1981, 1982). The first parallel is in the diagnosticity effect: The greater the departure from normal usage, the more the meaning of the combination differs from a simple combination of the meanings of its parts. Second, and more importantly, both views agree on modeling combinatorial semantics as interactions between intentional representations. However, although the Osherson and Smith work provides a detailed model of semantic combination for adjectives and nouns, it does not provide a solution to the problem of noun-verb semantic combination. Verb meanings convey relational frames, rather than single featural dimensions, so that we will need to go beyond the kinds of dimension-plus-value representations that may suffice for simple adjectives. Moreover, a feature-list model of noun meaning is inadequate to capture the kinds of representational density arguments made above.

Indeed, recent research by Medin and Shoben (1988) suggests that simple feature-list models may be inadequate to model even some adjective-noun combinations. They point out a disadvantage of the Osherson and Smith model: It predicts that a given adjective affects only one dimension of a noun's meaning; therefore the model cannot capture interactions among different dimensions. Medin and Shoben have demonstrated such dimensional interactions in judged typicality. For example, when rated as a *large spoon*, a wooden spoon is more typical than a metal spoon; when judged as a *small spoon*, the typicality order reverses. Results of this kind lend support to the notion that, in general, modeling conceptual combination may require modeling complex structural interactions among different dimensions.

Concluding Remarks

We have studied comprehension processes by using sentences in which the noun and the verb are sufficiently mismatched that subjects must engage in active processing to interpret the sentence. These results indicate that under such conditions it is verbs that adjust to nouns rather than the other way around. We considered various explanations for the verb mutability effect and concluded that neither outnumbering of the verb by nouns nor differential polysemy can be the sole explanation. We therefore conjecture two further factors that contribute to the verb mutability effect. The first difference is functional: Verbs function as predicates over objects, while nouns serve to establish reference to individual objects (including conceptual objects). The second difference is representational: At least for concrete terms, we conjecture that noun representations may be typically more internally cohesive than verb representations and therefore less easily altered.

The pattern of verb adjustment suggests a middle course between an extreme contextual negotiation position, in which words have no inherent meaning, and meaning is entirely contextually bound, and a fixed-meaning approach, in which rigid word meanings are simply concatenated. Change of meaning does occur to accommodate contextual constraints, but that change involves computations over the internal structure of the word meanings, particularly that of the verb. It appears that a rather fine-tuned semantic adjustment strategy may provide the best account of the comprehension of novel noun-verb combinations. Finally, we conjecture that it is typically the domain-specific components of a verb--the specific dimensional statives, such as possession or location--that are the first to go.

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Authors' Notes

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Footnotes

[1]Talmy (personal communication, 1980) mentions a similar phenomenon. He asked people to describe what they imagined for the sentence "She wafted through the crowd." People tended to describe a woman strolling gracefully through a crowd, changing direction frequently in response to local interactions. Again, people altered the notion of *wafting* to be some motion a person could do; they did not reinterpret the subject *she* to be something that could *waft*.

[2]The term "argument specification" is used here to preserve neutrality as to whether to invoke selectional restrictions or some other account of semantic compatibility.

[3]In fact, because the stimuli were taken randomly from standard word lists, the diagonal and above-diagonal matches vary somewhat in their naturalness. In particular, the diagonal entry "The car softened" seems a rather awkward match.

[4]In analyzing these results proportions were used throughout, because of unequal cell numbers. The above- and below-diagonal sectors each have 24 cells, while the diagonal sector has only 16 cells.

[5]In these analyses, the term "subject" refers to the retrace subjects.

[6]The second author served as rater. (At this point in the project, the second author was unaware of any specific hypotheses as to the results. However, because only one rater was used, these results should be taken as suggestive.)

[7]Note that the rate of Minimal Subtraction responses is elevated for concrete objects, due to the fact that the Minimal Subtraction choice was a literal paraphrase for the concrete objects.

[8]It should be noted, however, that it is possible that we simply guessed wrong in constructing the pragmatic interpretations. It is impossible to rule out the possibility that subjects would have opted for the pragmatic choice given a different set of pragmatic amplifications.

[9]An interesting prediction that follows from this is that 'old' verbs that have been in the language for a long time should be more polysemous than 'new' verbs that have recently been added.

[10]This work was begun in collaboration with Albert Stevens, who suggested the noun-noun issue.

[11]This effect of head noun vs. predicate noun is also present in Hampton's (in press) results with sentences like "The noun which is also a noun." In fact, the asymmetry between the two nouns poses a problem for his theoretical approach, which is simply to combine features of the two separate concepts.

[12]To evaluate this claim the notion of *comparable* nouns and verbs must, of course, be specified. At a minimum, the factors to be equated include word frequency and morphological complexity; concreteness, imagery, and hierarchical abstractness (i.e., whether basic level, superordinate, or subordinate) might also be important.

[13]Interestingly enough, noun extension is less likely to be analogy-based and more likely to consist of a chain of different kinds of associations, as Lakoff (1987) documents. As Nagy (personal communication, May 1986) put it, "Verbs are analogous, nouns metonymous."

Table 1

Results of Experiment 1: Sample responses to matched and under-matched (semantically strained) sentences

Matched
The politician worshipped
The public servant praised God.
The man in charge of public affairs gave praise.
The candidate looked to his campaign manager for advice on every detail.
Under-matched
The lizard worshipped
The hypocritical person went to church.
The pet is thankful for the hand that feeds it.
The chameleon stared at the sun in a daze.
The car worshipped
The vehicle only responded to him.
The automobile loved a good driver.
Someone's vehicle was given a rest on a Sunday.
The responsibility worshipped
He never minded having a heavy work load.
They fulfilled their social obligations by going to church.
The commitment prayed.

Table 2

Sample stimulus materials from Experiment 3b

Concrete Object: *Ernie lost a book.*	
M.S.	Ernie misplaced a volume, and now he could not find it.
R.S.	Ernie did not have a volume.
P.A.	Ernie ripped a volume.
CON.	Ernie was not a good badminton player, but he liked to read.
Human Object: *Keith lost a teacher.*	
M.S.	Keith's instructor stopped working for him, despite Keith's wishes.
R.S.	Keith no longer has the same instructor.
P.A.	Keith's instructor got mad and stopped working for him, which was very inconvenient.
CON.	Keith boiled some potatoes before class.
Abstract Object: *Joe lost doom.*	
M.S.	Joe was once very unhappy, but no longer is.
R.S.	Joe does not have ill fortune.
P.A.	Something very good happened to Joe, and he is no longer unhappy.
CON.	Joe lived in a brick house which he liked.

M.S. = Minimal Subtraction, R.S. = Radical Subtraction
P.A. = Pragmatic Amplification, CON. = Control

Figure 1

Matrix of noun-verb combinations used in Experiments 1 and 2, showing the diagonal, above-diagonal and below-diagonal sectors

	agree worship	shiver limp	soften cook	succeed weaken
daughter politician	The daughter agreed	The daughter shivered	The daughter softened	The daughter succeeded
mule lizard	The mule agreed	The mule shivered	The mule softened	The mule succeeded
car lantern	The car agreed	The car shivered	The car softened	The car succeeded
responsibility courage	The responsibility agreed	The responsibility shivered	The responsibility softened	The responsibility succeeded

Figure 2

Results of Experiment 1, using the retrace measure

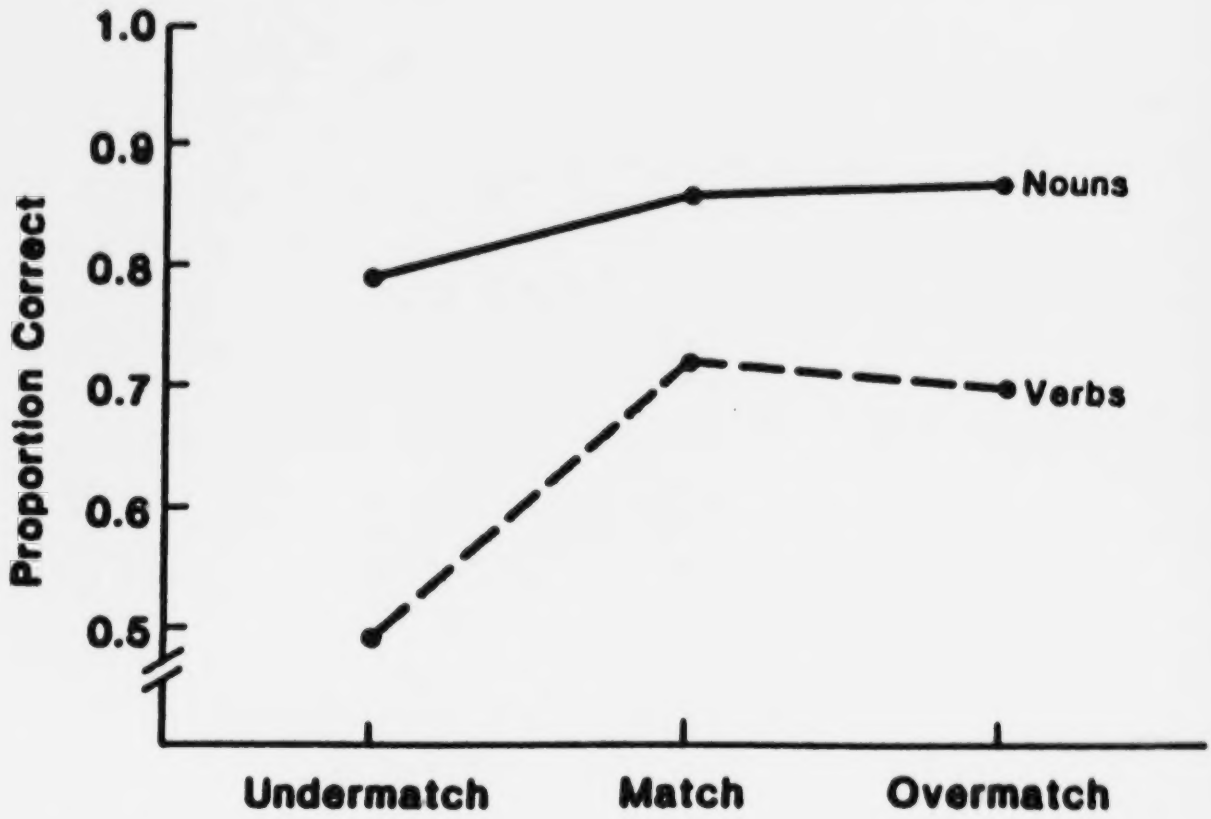


Figure 3

Results of Experiment 2, using the retrace measure

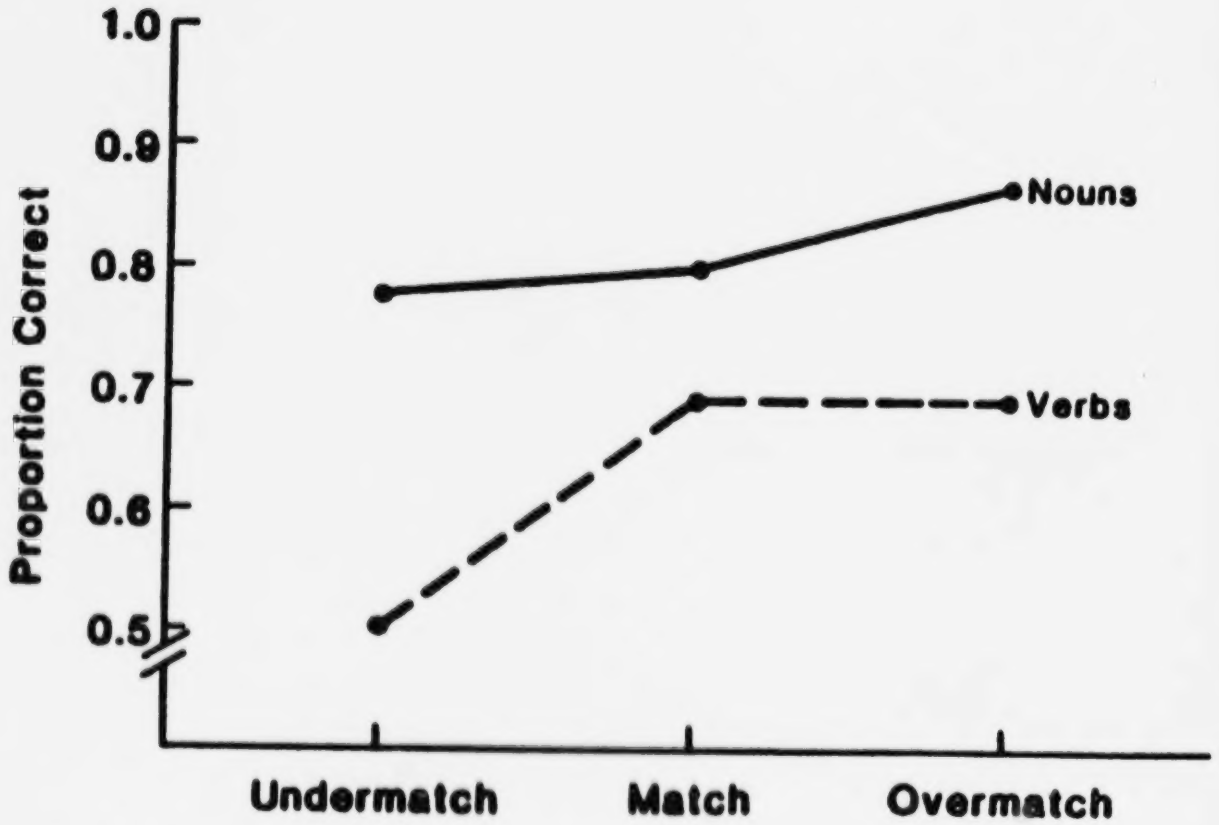


Figure 4

Matrix of verb-object combinations used in Experiment 3a.

8 verbs of possession	4 Noun Types: Concrete (book, vase)	Human (doctor, mechanic)	Abstract+ (loyalty, luck)	Abstract- (poverty, doom)
owned	Wayne owned a book			
kept				
bought		Nick bought a doctor		
borrowed				
traded			Dan traded loyalty	
stole				
lost				Jerry lost poverty
discarded				
	Predicted literal verb meaning	**Predicted metaphorical extension**		

Figure 5

Results of Experiment 3a: Proportions of adjustment strategies

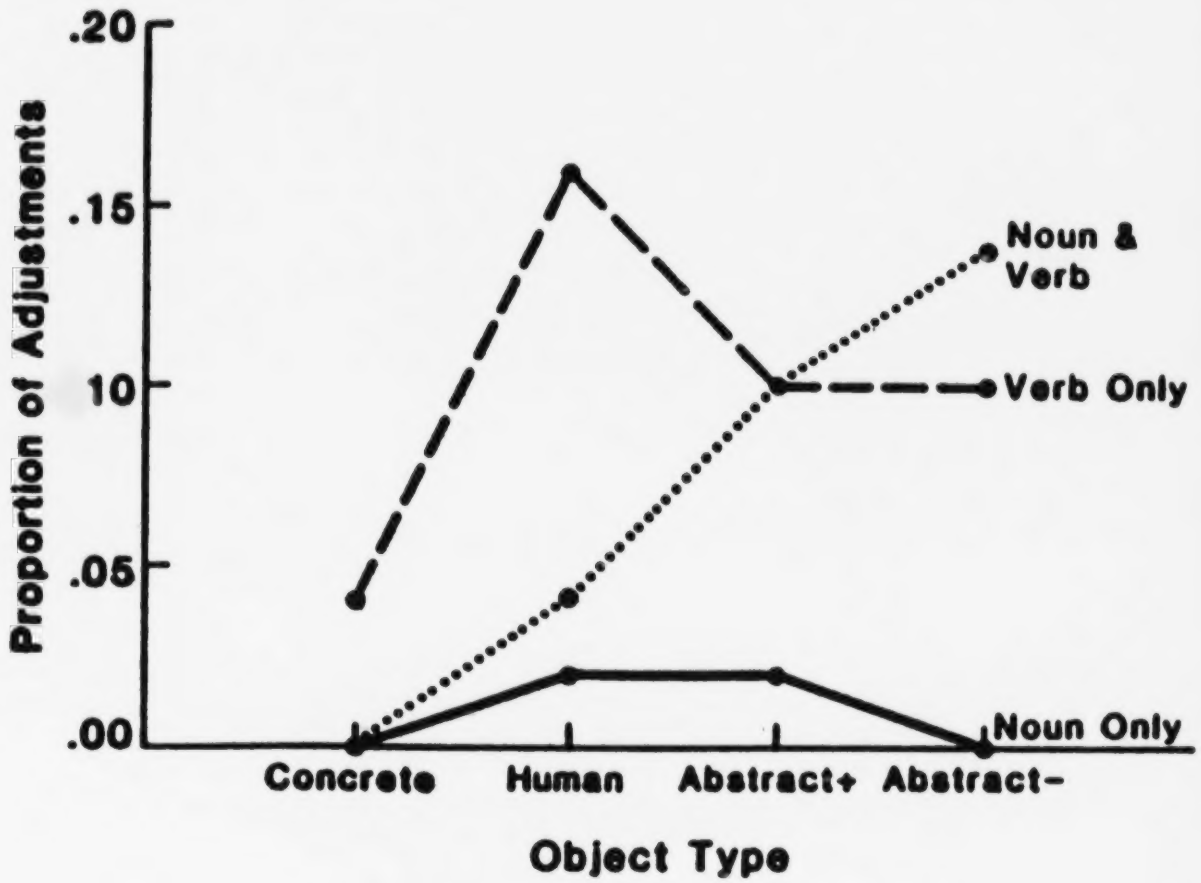


Figure 6

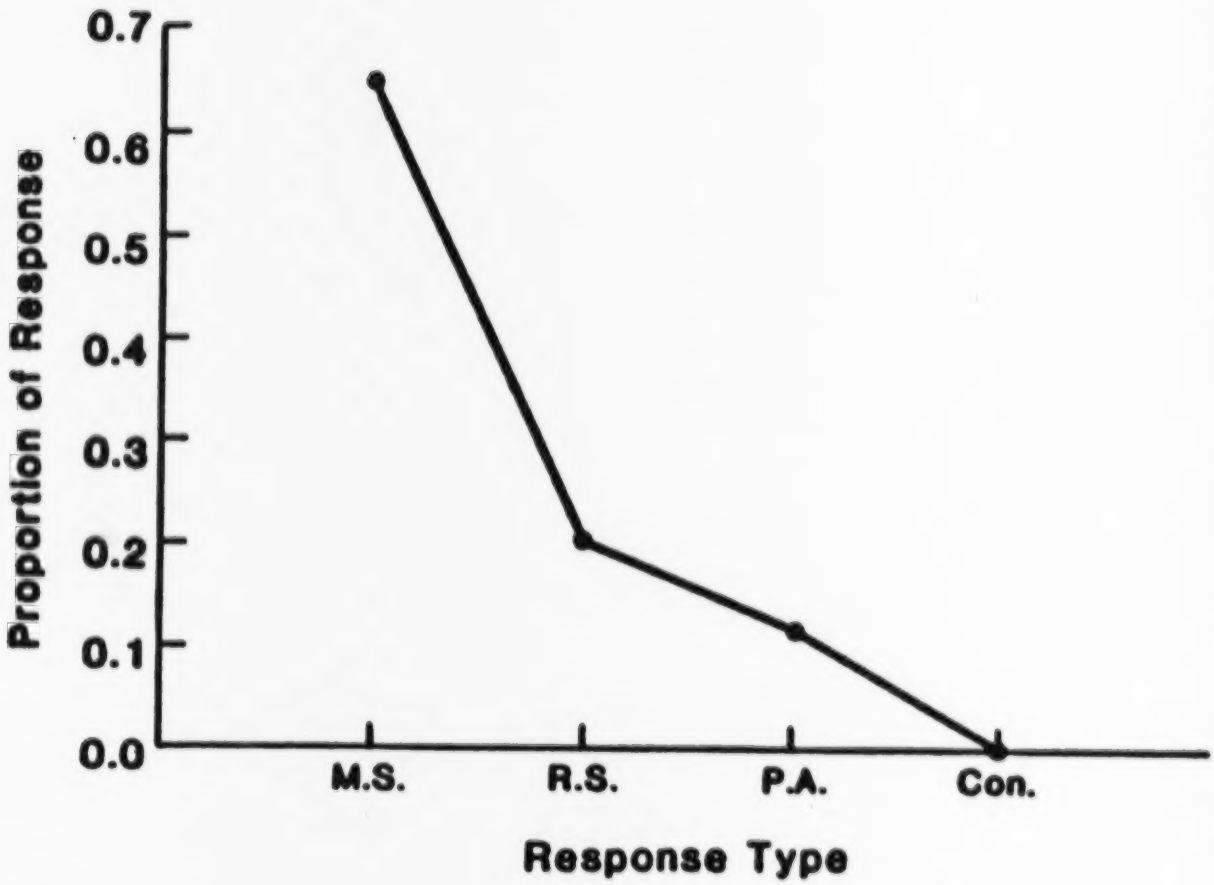
Sample matrix of verb-object combinations used in Experiment 3b.

Stimuli Constructed with Human Objects

6 Verbs of Possession	doctor	mechanic	accountant	teacher	plumber	mailman
kept	Steve kept a doctor					
bought		Jim bought a mechanic				
borrowed			Bob borrowed an accountant			
stole				William stole a teacher		
lost					Ivan lost a plumber	
discarded						Herbert discarded a mailman

Figure 7

Results of Experiment 3b: Proportion of each response type



Note: M.S. = Minimal Subtraction
P.A. = Pragmatic Amplification
R.S. = Radical Subtraction
CON. = Control

Figure 8

Results of Experiment 3b: Proportions of responses for each object type

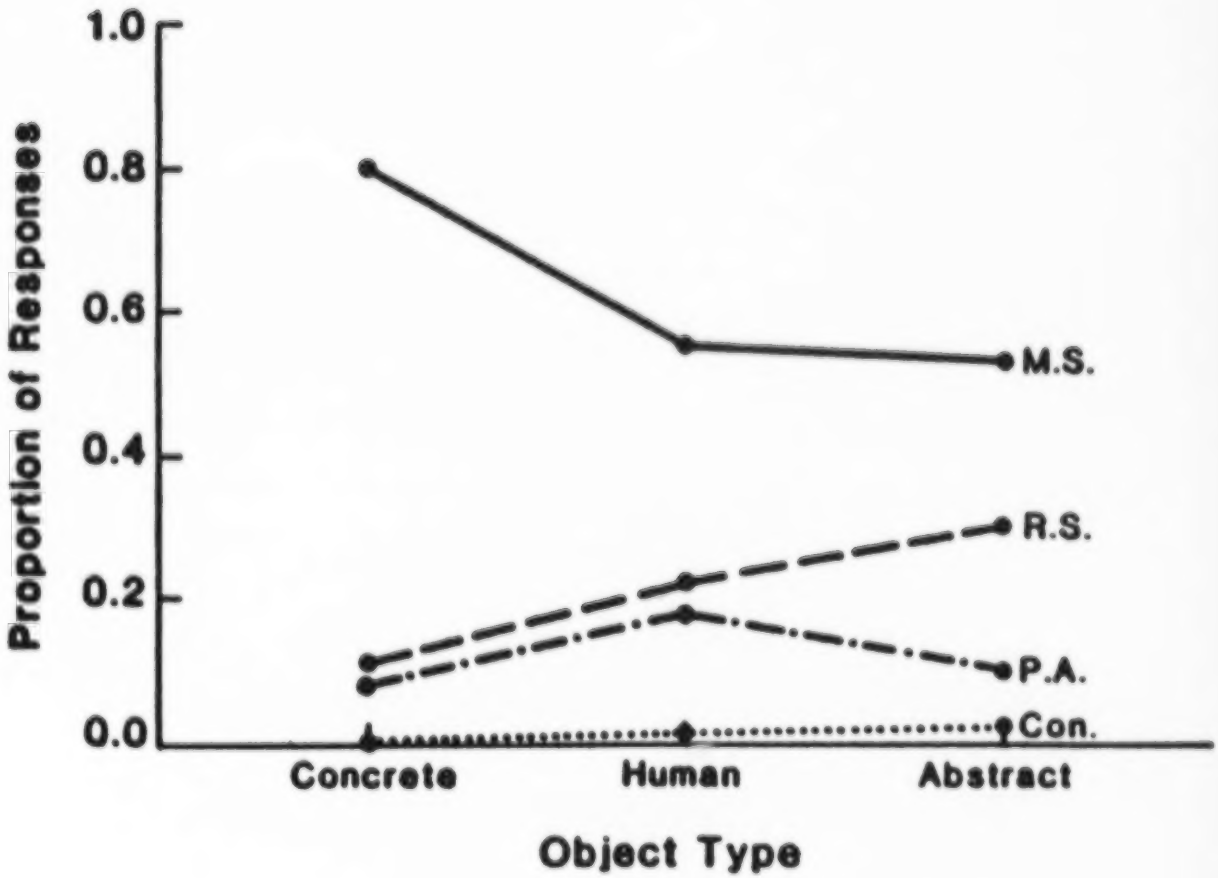


Figure 9

Representation of the verb semantic frame for "Ida gives Sam a vase."